

Sustainable nutrient solutions: enhancing finger millet growth and yield through integrated nutrient management

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ABSTRACT

Finger millet (*Eleusine coracana* L.) is a highly climate-resilient crop known for its adaptability to adverse environmental conditions and climate vagaries, such as drought, poor soil fertility, and low-input farming systems. The present study aims to assess the effects of organic and inorganic nutrient sources on periodic growth parameters like plant height, dry matter and leaf area index. Besides, grain and straw yield along with soil available nutrients were also assessed as influenced by various organic and inorganic treatments. The field experiment was conducted during the rainy season, 2023 at ICAR-Indian Agricultural Research Institute, Assam, under a humid sub-tropical climate with alluvial soil. The experiment employed a split-plot design with three replications, featuring main plot treatments of organic manure (1 t/ha), biofertilizer consortia, and farmyard manure (FYM@5 t/ha), while sub-plot treatments consisted of nitrogen (N) levels varying from 0 to 80 kg/ha. The results demonstrated that the combination of FYM application at 5 t/ha and 80 kg N/ha produced the most favourable outcomes in terms of growth parameters, grain and straw yield and residual soil fertility due to the synergistic effects of combining organic and inorganic nutrient management strategies.

Key words: Finger millet, Biofertilizer, FYM, Nitrogen, integrated nutrient management

India is the leading producer of millets. Almost all the states of India grow one or more millet crop species. A total of about 16.9 million tonnes of millets food grains are produced in India from nearly 12.7 million ha area, which constitutes about 6% of the national food grainbasket. Finger millet (1.1 mha, yielding 1.58 mt), pearl millet and sorghum account for more than 95% of the area under millets. Among them finger millet (*Eleusinecoracana*) is an important millet from nutrition point of view and finger millet has been recognized as a nutrient-dense crop widely grown

for both food and feed across Asia and Africa. It serves as a staple food for many, especially in under-privileged regions, due to its high nutritional value and versatility (Wambi *et al.*, 2021; Maharajan *et al.*, 2021). It is considered as the fourth most important millet in the world (Gupta *et al.*, 2012). Finger millet straw is also an excellent fodder for cattle. The flour from malted finger millet grain is commonly used in cakes, porridge, and infant foods, and is particularly recommended for diabetic patients. The productivity of finger millet is greatly influenced by the fertility status of the soil, and the quantity of fertilizer nutrients applied. Optimal management of these factors can significantly enhance yield and ensure the crop's contribution to both food and nutritional security in various regions. But the

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productivity of finger millet remains low, especially under the rainfed and sub-optimal nutrient application under the Assam conditions. The locally available organic nutrient sources are in use but the new and improved varieties are highly responsive to the applied fertilizers. Hence, an integrated nutrient management approach needs to be developed and the experiment was conducted with the hypothesis to obtain the most favourable combination of the organic and inorganic nutrient sources.

MATERIALS AND METHODS

The field experiment was conducted during the *kharif* season of 2023 at ICAR-IARI, Assam, under a humid subtropical climate with sandy alluvial soil. The experiment followed a split-plot design with three replications, comprising main plot treatments of organic manure (1 t/ha), biofertilizers, and farmyard manure (FYM, 5 t/ha), and sub-plot treatments of nitrogen levels ranging from 0 to 80 kg/ha. The finger millet variety “AAU-GSG-Marudhan 1 (Gossaingnaon Marudhan)” was used in the study. It is a medium-duration variety that matures in 110-120 DAT and has a yield potential of about 2-2.5 t/ha. For the plant height, four plants were selected randomly in each net plot in two lines and tagged. The plant height of these tagged plants was measured with a meter scale at 30, 60, and 90 DAT and at the harvest stage. The values were averaged and expressed in cm, measuring from the ground surface to the tip of the tallest plant part. The number of tillers per square meter was recorded by sampling two rows in each plot. Tillers were counted at 30, 60, and 90 days after transplanting (DAT) and at harvest. Leaf area of functional leaves carefully removed from each plant and grouped into three classes as per the size and leaf area was measured by “Automatic Leaf Area Meter”. For dry-matter accumulation, one-meter row of finger millet plants from the sampled area were selected and cut just above the ground level with a sickle at 30, 60, and 90 DAT and at harvest stage. These cut plants were allowed to sun-dry for 48 hours. After sun drying, the plants were dried in an oven at $65 \pm 5^\circ\text{C}$ for 48-72 hours or until the samples attained a constant weight. The average weight was then expressed in grams per

plant. The available N was estimated through alkaline potassium permanganate method proposed by Subbiah and Asija (1956); available P by Bray and Kurtz (1945), as referenced by Jackson (1973) and K by flame photometer using 1 N ammonium acetate extract method. The ear head obtained from each net plot area were threshed manually and grain yield was recorded and converted into kg/ha and the straw yield in each net plot was computed by deducting the grain yield from the biological yield. It was expressed on hectare basis.

RESULTS AND DISCUSSION

The data on plant height of finger millet at different growth stages indicates that both organic and inorganic nutrient management practices significantly influenced plant growth. Among the organic treatments, the application of FYM @ 5 t/ha consistently resulted in the tallest plants across all growth stages, reaching a maximum height of 107.8 cm at harvest. This may be attributed to the improvement in soil-physical properties, hydraulic conductivity, and the balanced availability of NPK due to FYM application, which enhances plant growth (Thumar *et al.*, 2016). Similarly, Prabhakar *et al.*, (2017) observed that adequate FYM application at rates of 7.5 to 10 t/ha supports better root development. Moreover, seed treatment with *Azospirillum brasilense* (a nitrogen-fixing bacterium) and *Aspergillus awamori* (a phosphorus-solubilizing fungus) at 25g/kg of finger millet seed has been found to be). Hence, the application of biofertilizers to finger millet also resulted in higher crop growth attributes.

In the N management treatments, a clear trend was observed that the plant height increased with higher N application rates, ranging from 0 to 80 kg/ha. The highest plant height of 111.6 cm at harvest was recorded with 80 kg N/ha, underscoring the importance of nitrogen availability in maximizing plant growth in finger millet. Nitrogen plays a critical role in promoting vegetative growth, which in turn leads to increased plant height. These findings align with the results of Obeng *et al.*, (2012). Furthermore, Rakesh *et al.*, (2021) found that nitrogen application in cereals helps to increase the number and size of internodes, contributing to greater plant height with

higher doses of nitrogen. Several researches, including Rakesh *et al.*, (2021) have also reported that applying 80 kg N/ha resulted in significantly higher plant height of finger millet compared to 40 and 60 kg N/ha. It shows the crop growth advantage with higher N doses, however it remained statistically at par with 40 and 60 kg N/ha. The results indicate that the response with N application may plateau after 60 kg/ha. Nigade and More (2013) have also reported greater finger millet height with higher fertilizer levels.

The dry matter accumulation also followed a similar trend as that of plant height, with significant differences observed among the treatments. The application of FYM at 5 t/ha resulted in the highest dry matter accumulation at 90 DAT (578.2 g/m²), it might be the efficacy of FYM in enhancing biomass production. The biofertilizer application also remained significantly superior over farmers practice of organic manure application. It indicated that plant growth is likely to be affected with biofertilizer application due to its role in improving nutrient availability, particularly phosphorus. It influenced growth parameters like plant height, leaf area index, and dry matter production. The organic manures had slow release of nitrogen due to its slow mineralization, which helped in the availability of nutrients commensurate with the growth and development and thus resulted in higher growth parameters (Channabasanagowda *et al.*, 2008).

Similarly, N management had a pronounced effect on dry matter accumulation, with the highest accumulation recorded in the 80 kg N/ha treatment (585.7 g/m²) at 90 DAT. The progressive increase in dry matter with higher nitrogen levels suggests that nitrogen plays a critical role in biomass production, likely through its influence on photosynthesis and overall plant metabolism. Inoculating nitrogen fixing microorganisms, *viz.* biofertilizers like *Azospirillum* spp., *Azotobacter* spp. (20g/kg) significantly improves the plant height and dry weight of finger millet. The improved physio-chemical properties and availability of nutrients at a slow rate for a longer period with the use of organics might be responsible for higher tillers, maximum leaf area and increased photosynthesis leading to accumulation of significantly higher dry matter.

The leaf area index (LAI) is also an important indicator of the crop's ability to intercept light, which directly impacts photosynthesis and growth. In this study, the LAI increased with the application of organic and inorganic nutrients, with FYM at 5 t/ha and 80 kg N/ha treatments showing the highest LAI at 90 DAT (3.71 and 3.65, respectively). The significant increase in LAI with these treatments suggests that both organic and inorganic nutrient sources enhance leaf development and canopy expansion, leading to better light interception and potentially higher yields. The larger leaf area is likely to increase photosynthetic activity, resulting in a greater production of photosynthates in finger millet throughout all stages of growth have also reported similar findings.

The number of tillers is an important yield attribute in finger millet and it was significantly influenced by nutrient management. The application of FYM at 5 t/ha resulted in the highest number of tillers at all growth stages, with a maximum of 132.5 tillers/m² at 90 DAT. This could be due to the slow and steady release of nutrients from FYM, which supports sustained tiller development and minimum tiller mortality at later stages. The biofertilizer application also contributed to an increase in tiller number, although to a lesser extent than FYM. Similarly, findings have been reported by that the addition of FYM along with RDF resulted in taller plants with a greater number of tillers, functional leaves and dry matter accumulation/hill in finger millet.

Among the N treatments, the number of tillers increased with higher nitrogen application rates, reaching 155 tillers/m² at 80 kg N/ha. This indicates that nitrogen availability is a key factor in promoting tillering, which is crucial for achieving high grain yields. The significant differences between the nitrogen treatments at various stages suggest that optimizing nitrogen application is essential for maximizing tiller production and, consequently, the yield potential of finger millet. Similarly, Rakesh *et al.*, (2021) found that increasing nitrogen levels significantly boosted the number of tillers per hill in finger millet. The highest tiller count was achieved with the application of 80 kg N/ha, consistently yielding around 5.7 tillers/hill across three years of study. This high-

lights the importance of adequate nitrogen fertilization for improving finger millet growth. Biofertilizer and organic manure @ 1 t/ha also improved soil nutrient levels over the control, highlighting the benefits of organic inputs in maintaining soil health. The grain yield of finger millet was significantly influenced by both organic and inorganic nutrient management practices (Fig.1). The highest grain yield was observed with FYM@ 5 t/ha (1.70 t/ha), which was significantly greater than with organic manure (1.35 t/ha) and biofertilizer (1.38 t/ha). The FYM application increased grain yield by 25.9% over organic manure and 23.2% over biofertilizer, likely due to its balanced and prolonged nutrient availability, which enhances dry matter accumulation, plant height, and tiller count and ultimately resulted in the

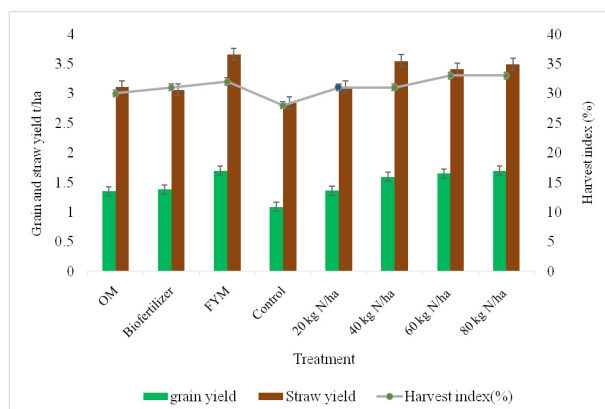


Fig. 1. The grain, straw yield and harvest index of finger millet as influenced by integrated nutrient management

highest grain yield (1.70 t/ha). The response of N was recorded up to 80 kg N/ha, however the yield obtained under control was as low as 1.09 t/ha. This yield enhancement with N application (55.96% over control) highlights nitrogen's critical role in enhancing finger millet productivity. Biofertilizers and organic manure also improved yields compared to the control, although to a lesser extent.

The straw yield of finger millet was also significantly influenced by both organic and inorganic nutrient management practices. The highest straw yield among the organic treatments was observed with the application of FYM @ 5 t/ha (3.66 t/ha), which was significantly higher than the other organic treatments. Straw yields were comparable between biofertilizer (3.06t/ha) and organic manure @1t/ha (3.11 t/ha), however, both treatments were significantly higher than the control treatment (2.84 t/ha). For the inorganic treatments, the highest straw yield was recorded with the application of 40 kg N/ha (3.55t/ha), although the 60 kg N/ha(3.41t/ha) and 80kgN/ha(3.49t/ha) treatments yielded similarly. The control treatment had the lowest straw yield (2.84 t/ha). The harvest index (HI) was not significantly influenced by the organic nutrient management practices. The highest HI was recorded with FYM @ 5 t/ha (32), although this was statistically at par with the other organic treatments. In the inorganic treatments, the highest HI was recorded at the 80 kg N/ha application rate (33), which was comparable

Table 1. Plant height of finger millet as influenced by organic and inorganic nutrient management

Treatment	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	At harvest
<i>Organic nutrient management</i>				
Organic manure @ 1 t/ha	59.0	70.5	85.6	95.0
Biofertilizer*	61.6	76.5	91.7	102.4
FYM @ 5t/ha	63.1	79.1	94.7	107.8
SEm ±	6.5	1.8	1.4	2.2
LSD (p=0.05)	NS	NS	5.9	8.8
<i>Nitrogen management (N kg/ha)</i>				
Control	54.8	63.0	79.3	90.3
20	57.3	71.3	88.2	99.3
40	62.0	76.3	91.4	101.3
60	65.3	80.6	95.8	106.6
80	66.6	85.5	99.4	111.6
SEm ±	1.1	2.1	3.3	2.5
LSD (p= 0.05)	3.4	6.2	9.9	7.3

to the 60 kg N/ha (33) and 40 kg N/ha (31) treatments. The control treatment had the lowest HI(28). The HI values for the inorganic treatments increased with higher nutrient application rates, with significant differences observed between the treatments.

The results from Table 3 indicate that soil fertility, as measured by available nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O), is significantly influenced by organic amendments and N management practices in finger millet cultivation. Farmyard manure (FYM) @ 5 t/ha significantly increased the availability of N, P_2O_5 , and K_2O outperforming other treatments. This suggests

that FYM is highly effective in enhancing soil fertility by improving nutrient content and soil structure. The available N, P_2O_5 , and K_2O in the soil were significantly influenced by various organic amendments and nitrogen management practices. Farmyard manure (FYM) @ 5 t/ha resulted in the highest available nitrogen (183.60 kg N/ha), phosphorus (13.56 kg P_2O_5 /ha), and potassium (132.20 kg K_2O /ha). This indicates a substantial enhancement in soil fertility, significantly outperforming the other organic treatments and the control. Biofertilizer application showed moderate improvement in available N (175.80 kg N/ha), P_2O_5 (11.93 kg/ha), and K_2O (128.50 kg/ha), which were

Table 2. Dry matter accumulation growth parameter of finger millet as influenced by organic and inorganic nutrient management

Treatment	Dry matter accumulation (g/m ²)			Leaf area index			Number of tillers/m ²		
				30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
	30 DAT	60 DAT	90 DAT						
<i>Organic nutrient management</i>									
Organic manure@ 1 t/ha	128.8	389.2	523.1	1.42	2.16	3.49	76.6	111.2	117.5
Biofertilizer	135.8	399.6	570.4	1.55	2.68	3.60	80.2	114.4	121.1
FYM@ 5t/ha	140.7	446.1	578.2	1.62	2.80	3.71	89.1	126.7	132.5
SEm ±	1.9	8.9	9.9	0.02	0.03	0.09	2.2	1.6	3.9
LSD (p= 0.05)	7.7	36.0	39.7	NS	0.14	NS	8.9	6.8	15.3
<i>Nitrogen management (N kg/ha)</i>									
Control	114.6	378.1	528.2	1.46	2.16	3.55	58.9	92	97.6
20	129.3	403.2	541.4	1.49	2.51	3.57	71.9	100.6	107.3
40	135.0	409.6	557.4	1.52	2.64	3.60	80.1	112.2	116.3
60	146.6	423.6	572.6	1.56	2.66	3.63	94.9	135.1	142.6
80	150	443.6	585.7	1.59	2.76	3.65	103.9	147.6	155.0
SEm ±	4.0	10.9	12.9	0.04	0.05	0.11	2.6	2.7	4.1
LSD (p= 0.05)	11.8	32.0	38.0	NS	0.15	NS	7.7	8.2	12.2

Table 3. Effect of crop establishment methods and nitrogen management on initial available N, P_2O_5 and K_2O (kg/ha) in finger millet.

Treatment	Available N	Available P_2O_5	Available K_2O
<i>Organic nutrient management</i>			
Organic manure@ 1 t/ha	172.20	10.56	126.30
Biofertilizer	175.80	11.93	128.50
FYM@ 5t/ha	183.60	13.56	132.20
SEm ±	5.143	0.30	3.979
LSD (p= 0.05)	15.00	1.210	15.62
<i>Nitrogen management (N kg/ha)</i>			
Control	146.67	10.97	123.67
20	173.33	11.76	126.67
40	181.00	12.20	128.67
60	185.00	12.53	132.00
80	200.0	12.6	134.0
SEm ±	1.70	0.94	3.611
LSD (p= 0.05)	6.70	0.32	10.53

higher than the control but lower than FYM @ 5 t/ha. Organic manure @ 1 t/ha also enhanced soil fertility, recording 172.20 kg N/ha of available nitrogen, 10.56 kg P_2O_5 /ha, and 126.30 kg K_2O /ha. This treatment was significantly better than the control but less effective compared to FYM @ 5 t/ha. The control plot, which did not receive any additional organic amendments, recorded the lowest available N (146.67 kg/ha), P_2O_5 (10.97 kg/ha), and K_2O (123.67 kg/ha). This demonstrates the necessity of nutrient management practices for improving soil fertility.

The application of nitrogen in increasing amounts (from 20 to 80 kg N/ha) resulted in a significant increase in the initial soil nutrient status. The highest nitrogen application rate (80 kg N/ha) led to the maximum available nitrogen (200 kg N/ha), phosphorus (12.6 kg P_2O_5 /ha), and po-

tassium (134 kg K_2O /ha). This indicates a positive correlation between nitrogen application rates and soil fertility. Lower nitrogen application rates (20, 40, and 60 kg N/ha) resulted in progressively lower available N, P_2O_5 , and K_2O compared to the 80 kg N/ha treatment but still improved over the control.

The one-year study carried out Assam indicates that the use of FYM in joint application of 80 kgN/ha resulted in higher growth and productivity of finger millet. The optimization of standard N dose for new nutrient-responsive cultivars with optimum N doses can enhance profitable adoption of millets in larger areas. These findings suggest that combining organic and inorganic nutrient sources can optimize nutrient uptake, improve soil health, and support sustainable agricultural practices in semi-arid regions.

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